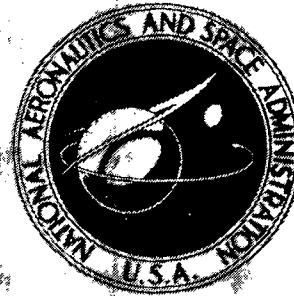


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**CASTING COPPER TO TUNGSTEN
FOR HIGH-POWER ARC LAMP CATHODES**

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1. Report No. NASA TM X-2865		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle CASTING COPPER TO TUNGSTEN FOR HIGH-POWER ARC LAMP CATHODES				5. Report Date August 1973	
				6. Performing Organization Code	
7. Author(s) Herbert A. Will				8. Performing Organization Report No. E-7456	
9. Performing Organization Name and Address Lewis Research Center National Aeronautics and Space Administration Cleveland, Ohio 44135				10. Work Unit No. 502-25	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546				13. Type of Report and Period Covered Technical Memorandum	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract <p>A method for making 400-kW arc lamp cathodes is described. The cathodes are made by casting a 4.45-cm- (1.75-in. -) diameter copper body onto a thoriated tungsten insert. The addition of 0.5-percent nickel to the copper prevents voids from forming at the copper-tungsten interface. Cathodes made by this process have withstood more than 110 hours of operation in the 400-kW arc lamp at the Lewis Research Center.</p>					
17. Key Words (Suggested by Author(s)) Casting Arc lamp Vacuum Cathode Copper Vacuum melting Tungsten Induction heating				18. Distribution Statement Unclassified - unlimited	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 10	
				22. Price* \$3.00	

* For sale by the National Technical Information Service, Springfield, Virginia 22151

CASTING COPPER TO TUNGSTEN FOR HIGH-POWER

ARC LAMP CATHODES

by Herbert A. Will

Lewis Research Center

SUMMARY

Cathodes for a 400-kilowatt arc lamp are fabricated by vacuum casting. The cathode consists of a 4.45-centimeter- (1.75-in. -) diameter copper body with a thoriated tungsten insert for the emitting surface. The copper body of the cathode is hollow and is cooled from the rear with high-pressure water.

The cathode is cast in two steps.- The first step consists of casting a small amount of copper and nickel onto a thoriated tungsten insert. The second step consists of re-casting the cathode with more copper in order to dilute the nickel in the casting to 0.5 percent. The nickel is used as a wetting agent to prevent voids from forming at the copper-tungsten interface. Cathodes made by this process have withstood more than 110 hours of operation in the arc lamp.

INTRODUCTION

The largest space environment chamber in the world is operated at the Lewis Research Center's Plum Brook Station. The chamber measures 30.5 meters (100 ft) in diameter and 39.6 meters (130 ft) high. A large solar simulator was designed and built at Lewis for installation in the space chamber. The solar simulator produces an irradiance of one solar constant over an area of 84 square meters (904 ft²)(ref. 1). The radiation is obtained from two 400-kilowatt argon arc lamps. The power rating of each lamp is about 20 times the power rating of today's largest commercially available lamp. The construction of an arc lamp suitable for this purpose resulted in many technical problems. One of the major problems was the development of long-lived electrodes.

The lamp is a stainless-steel pressure vessel filled with argon. Within this tank a 4 000-ampere direct-current arc is maintained between two copper electrodes. The electrodes are cooled from the rear by high-pressure water. The anode has a large

area and is relatively easy to water cool. The cathode contains a thoriated tungsten disk bonded into a copper body, as shown in figure 1. The thoriated tungsten is used as a low-work-function emitting surface for the thermal emission of electrons. During operation, the arc attaches itself to the upper edge of the inverted cone which is machined in the center of the thoriated tungsten. As a result, there is a large amount of localized heating of the tungsten. In order to prevent the tungsten from melting, there must be a good thermal path between the emitting surface and the cooling water.

This report documents the procedure and equipment used for casting these cathodes. The main problem in the casting process is the bonding of the thoriated tungsten to the copper electrode. If there is a poor bond between the copper and tungsten or if there are voids in the copper, the thermal conductance is reduced and the tungsten starts to melt. Many of the cathodes previously made for the arc lamp failed after a few hours use because of excessive melting of the tungsten.

When copper is cast onto tungsten, there is a tendency for voids to form at the interface. This is caused by incomplete wetting of the tungsten by the copper. The voids can be eliminated by adding a wetting agent (nickel) to the copper during the casting process.

APPARATUS

The cathode is made by vacuum casting copper and tungsten in a graphite crucible. A diagram of this crucible is shown in figure 2. The crucible is machined from a high-density graphite. With this type of graphite the crucible can be reused about six times before it is destroyed by the liquid copper.

The graphite crucible and the copper are heated by a radiofrequency (RF) induction generator. The vacuum system and RF induction generator are shown in figure 3. The RF generator has a power output of 20 kilowatts at a frequency of 450 kilohertz. The vacuum system consists of a 20.3-centimeter- (8-in. -) diameter oil diffusion pump and associated mechanical vacuum pump. The temperature of the graphite is monitored by means of an optical pyrometer.

The vacuum chamber is shown in figure 4. The graphite crucible is positioned about halfway up from the bottom of the chamber. The crucible is supported by placing it on top of a small-diameter quartz tube extending up from the baseplate.

The vacuum chamber is mated to the diffusion pump by means of the baseplate adapter shown in figure 5. A flat bar (fig. 5(b)) is bolted to the bottom of the baseplate and to this is bolted a support rod (fig. 5(c)). A 0.38-meter- (15-in. -) long quartz tube is chosen so that it just slides snugly over the O-ring on the support rod. The crucible is then supported by placing it on the top of the quartz rod.

PROCEDURE

Initially, a new graphite crucible is put into the quartz vacuum chamber and evacuated. After the vacuum chamber has reached 10^{-4} torr, the RF generator is turned on. The graphite crucible is then heated to about 1200°C for a few minutes to outgas the impurities in the graphite.

The tungsten that is to be bonded to the copper is shown in figure 6. The tungsten is first degreased in trichloroethylene (CHCl_3) for a few minutes. Then it is etched in a 1/1 mixture of concentrated hydrofluoric acid (HF) and red fuming nitric acid (HNO_3). The etching is very rapid and should be allowed to proceed for only about 4 to 5 seconds. (Use a fume hood. The fumes given off by the acid are toxic.) The reaction can be stopped by flushing with water.

The tungsten electrode is then put into the graphite crucible with the flat side of the electrode down. The inside bottom of the crucible is indented slightly in order to center the tungsten electrode. Next pure nickel is put on top of the tungsten. The volume of nickel should be about 0.5 percent by volume of the copper (about 0.58 cm^3 (0.035 in.^3) for the crucible shown in fig. 2). Next a 5-centimeter- (2-in.-) diameter disk of copper (99 percent, oxygen free) 1.9 centimeters (0.75 in.) thick is put on top of the nickel wire. The copper is previously cleaned by etching for 10 minutes in 5N nitric acid. A cover (to prevent evaporation of copper) is put on the crucible and the crucible is then put into the vacuum chamber.

When the vacuum has reached 10^{-5} torr, the RF generator is turned on. The temperature of the crucible is slowly brought up to 1300°C over a period of about 10 minutes. The temperature is held at 1300°C for about 5 minutes, and then the RF generator is turned off.

After cooling, a second piece of copper 5 centimeters (2 in.) in diameter and 3.8 centimeters (1.5 in.) high is put into the carbon crucible. The crucible is then evacuated and heated as before to about 1200°C . Note that, when the copper melts, the temperature of the crucible will hold at 1083°C for a few minutes. After the copper melts, the temperature should be brought up to 1200°C and held there for about 5 minutes before shutting off the RF generator.

The casting is done in a two-step process because the tungsten is wetted by the copper better if there is a relatively high percentage of nickel present. Because nickel has a low thermal conductivity, there should be a minimum amount of it in the final casting. Thus the second step is to dilute the nickel in the copper casting to 0.5 percent. The final casting is shown in figure 7.

After the casting is completed, the tungsten and copper are machined into the final shape shown in figure 1.

CASTING QUALITY

Tungsten inserts were bonded to pure copper and to copper + 0.5 percent nickel castings. The castings made with pure copper had many voids at the tungsten interface. These were evident when the casting was machined into the final form. They resulted in holes in the water side of the electrode.

The voids can also be observed before machining by X-raying the final castings. The holes appear on the X-ray as small round dark areas around the tungsten. X-ray photographs of the electrodes cast with and without nickel are shown in figure 8. These are negative prints of the original X-ray photographs. Note that the X-ray of the casting with 0.5-percent nickel (fig. 8(b)) shows no evidence of voids.

The 0.5-percent nickel in the copper casting was found to reduce the thermal conductivity by 20 percent from that of pure copper. However, since the 0.5-percent nickel cathodes exhibit a lifetime of over 110 hours, it appears that the 20-percent decrease in thermal conductivity is not significant.

SUMMARY OF RESULTS

In designing the solar simulator for the Lewis Research Center's Plum Brook Station, a new method for fabricating high-power arc lamp cathodes was devised. The cathodes were made by casting a 4.45-centimeter- (1.75-in. -) diameter copper body onto a thoriated tungsten insert. The addition of 0.5-percent nickel to the copper prevented voids from forming at the copper-tungsten interface. Cathodes made by this process have withstood more than 110 hours of operation in the 400-kilowatt arc lamp at the Lewis Research Center.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, May 24, 1973,
502-25.

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1. Decker, Arthur J.; and Pollack, John L.: A 400 Kilowatt Argon Arc Lamp for Solar Simulation. NASA TM X-68042, 1972.

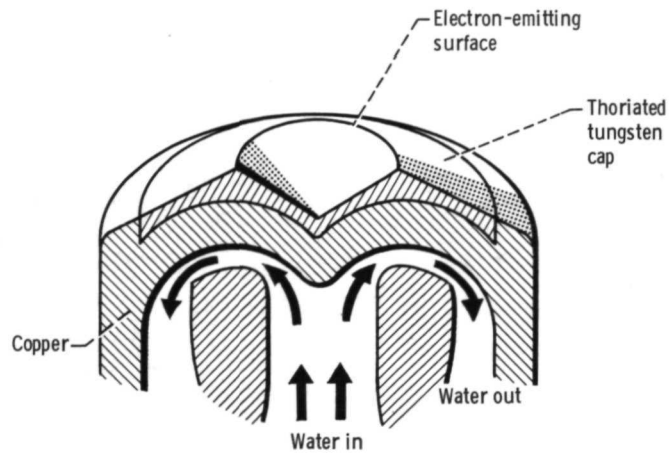


Figure 1. - Sectioned diagram of cathode. Diameter, 5 centimeters (2 in.).

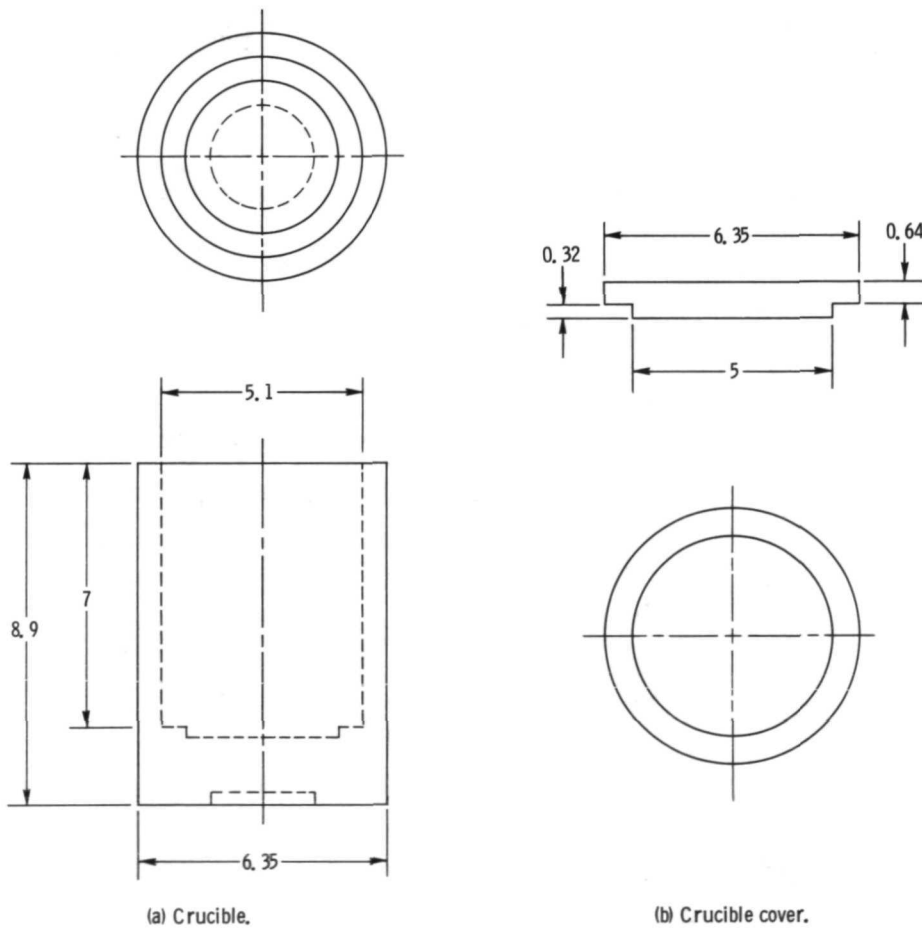


Figure 2. - Diagram of graphite crucible. (All dimensions are in cm.)

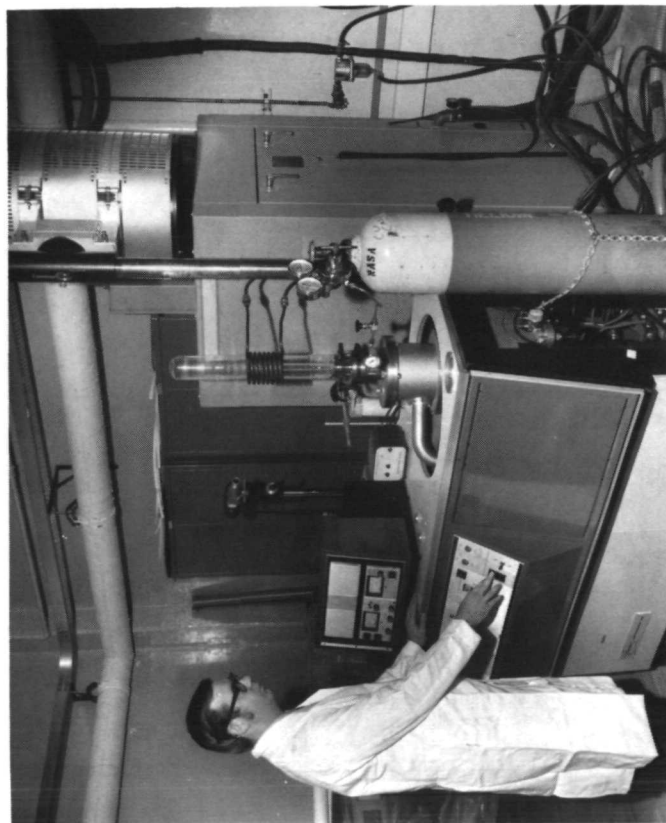


Figure 3. - Cathode-casting equipment.

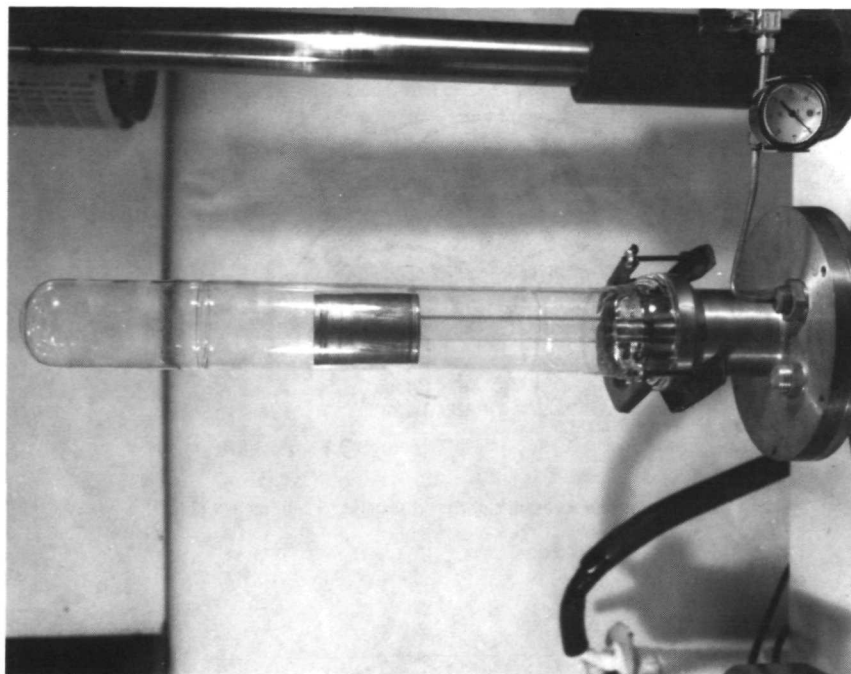


Figure 4. - Vacuum chamber. Height, 58 centimeters (23 in.); outside diameter, 80 millimeters; inside diameter, 76 millimeters. Quartz 75 mm ID O-ring joint used to mate vacuum system.

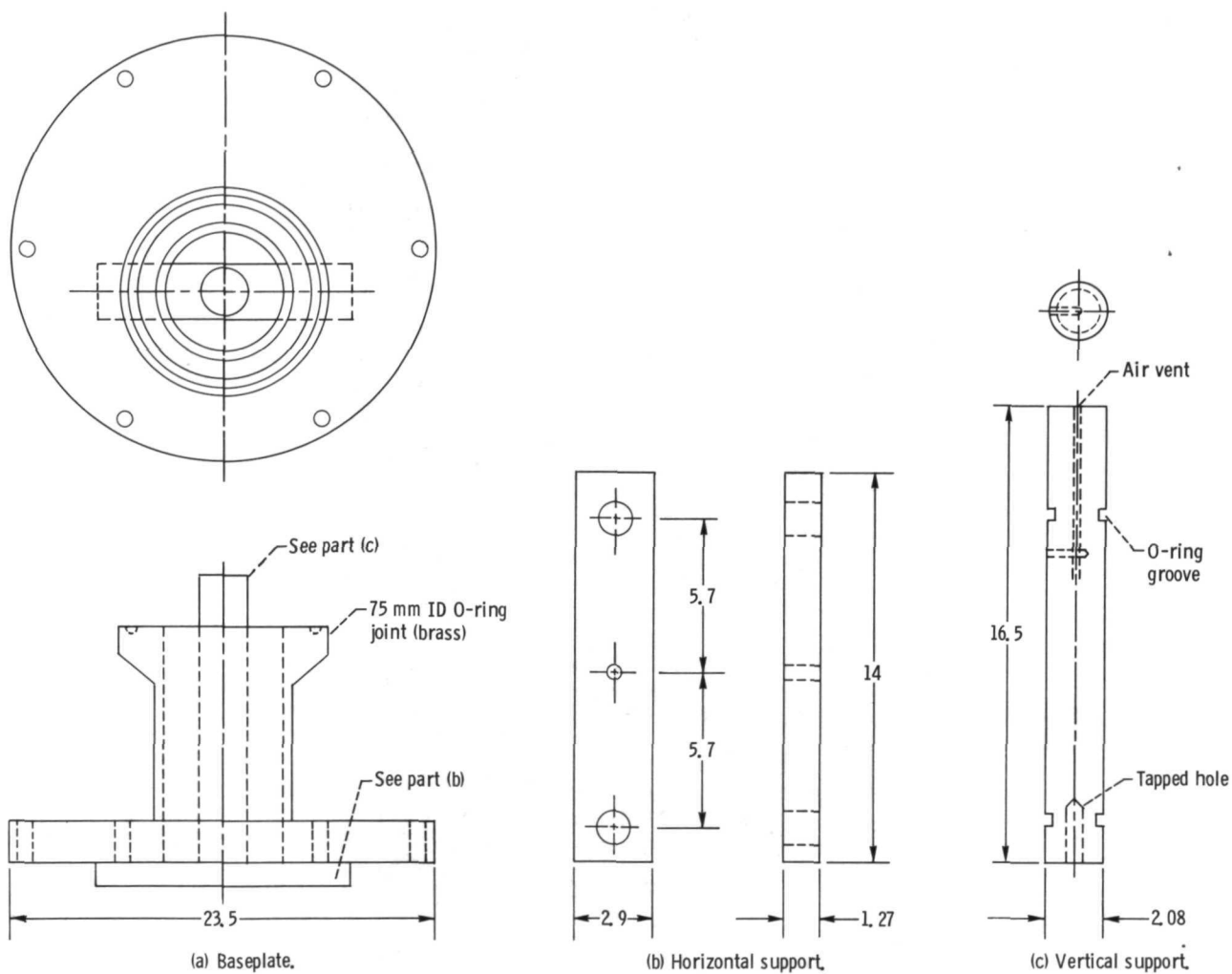
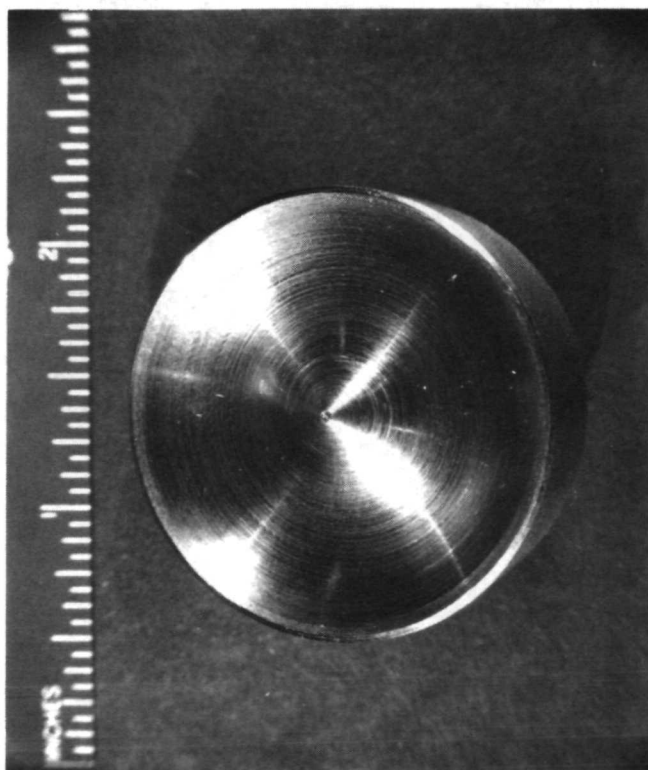


Figure 5. - Drawing of baseplate adapter. O-rings are chosen so that a quartz tube will just fit snugly over the O-ring. Dimensions are in centimeters.



(a) Curved side.

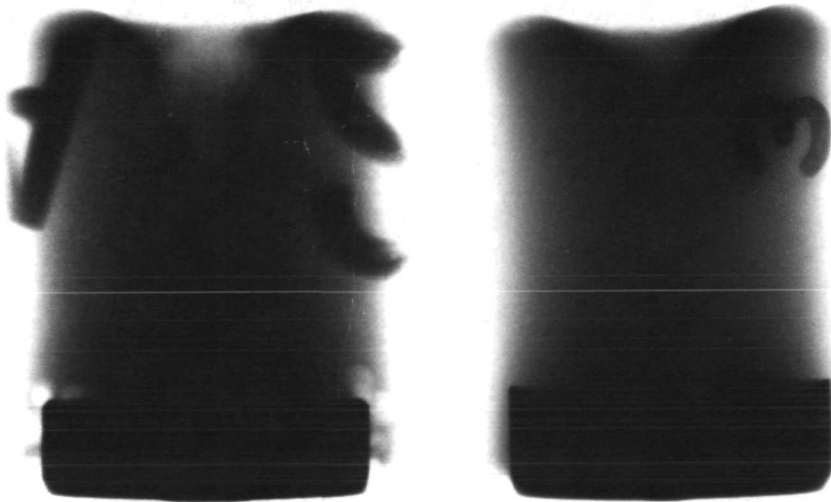


(b) Flat side.

Figure 6. - Tungsten electrode before casting in copper.



Figure 7. - Final casting - tungsten electrode in copper.



(a) Pure copper.

(b) Copper - 0.5-percent nickel.

Figure 8. - X-ray photograph of tungsten cast in copper.



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